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A.T.I.

20757

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Fisher, W. A. P.

Stress Analysis and Structures (7)
Structural Theory and Analysis Method (2)
Stress analysis - Photoelastic
method (90804)

20757

S.N.E. 2400

Photo-elastic examination of a cylindrical strut intended for recording compressive loads

Royal Aircraft Establishment, Farnborough, Hants

Gt. Brit. Eng.

Restr.

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Feb'47

7

photos, diagr

Photoelastic methods are used to determine the amount of stress distribution of a cylindrical steel strut 16 in. long and 6 in. diameter, mounted for measurement of compressive force by strain gauges, even when the end load is concentrated near the axis of the strut. Results show that the strut will be in sensibly uniform stress, under axial loading, for a distance of $1\frac{1}{2}$ in. each side of the middle section. Consequently, constancy of the strain load factor will be achieved well within 1% over the middle $8\frac{1}{2}$ in. of the bar.

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REPORT No: S.M.E. 3400

ATI No.

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ROYAL AIRCRAFT ESTABLISHMENT

Farnborough, Hants.

Incl 15
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PHOTO-ELASTIC EXAMINATION OF A CYLINDRICAL STRUT INTENDED FOR RECORDING COMPRESSIVE LOADS

by

W. A. P. FISHER, B.A., D.I.C.

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February, 1947.

ROYAL AIRCRAFT ESTABLISHMENT, FARNBOROUGH

Photo-Elastic Examination of a Cylindrical Strut
Intended for Recording Compressive Loads

by

W.A.P.Fisher, B.A., D.I.C.

R.A.E. Ref: SME.C3/8086/WAPF/159

SUMMARY

Photo-elastic methods are used to establish how much of a cylindrical steel strut, mounted for measurement of compressive force by strain-gauges, has uniform stress distribution, even when the end load is concentrated near the axis of the strut.

It is found that a strut 16 in. long, and 6 in. diameter has virtually uniform stress distribution over the middle $2\frac{1}{2}$ in.

Introduction

A weighbar, in the form of a cylindrical strut with rounded ends, had been tentatively designed for measuring, by means of strain gauges at its middle section, the compressive load exerted by a projected 100-ton testing machine.

The designed dimensions for the strut are shown in Fig.1, giving a length/diameter ratio of $2\frac{2}{3}$ which, (according to a conventional design rule*) when the resultant load is axially applied, should give a region of about 4" length over which the stress distribution is independent of the manner in which the end loads are applied.

When mounted on the testing machine, the strut is to be aligned by means of a centering device and bedded down on the seatings by the application of a 100-ton load. The areas in contact at its two ends would subsequently be a fraction of the total end area varying somewhat with the load.

It was required to show experimentally whether or not sufficient length had been allowed to produce a mean value of the strain on the perimeter of the middle section which would not vary under all likely conditions of end loading.

* According to this rule, the stress is independent of the end load distribution at a distance from the end greater than 1 diameter.

Experimental Method

A model of the strut was made from Catalin 800' to $\frac{1}{20}$ th scale, with end caps shaped as for the intended prototype. The model was loaded through a pair of these end caps by means of a special clamp. It was then placed in an immersion cell containing a mixture of liquids having the same refractive index as Catalin (see Appendix) and the fringe pattern photographed, using monochromatic light in a direction at right angles to the axis of the model. In this way, it was unnecessary to resort to slicing. All loadings were made at room temperature.

The distribution of end load was then changed by altering the shape of the bearing surface and the experiment repeated. In most of the arrangements, photographs were taken at different degrees of loading. The greater number of fringes with higher loads gave a sensitive indication of the stress distribution.

Four different cases were chosen, so as to embrace the extreme conditions of load distribution (maximum and minimum areas of contact) as well as the most probable. The arrangement in these four cases and the degrees of loading used are shown in Fig.2.

In Case 1, the end pieces were made in the form of truncated cones with spherical surfaces of equal radius to the end of the strut. The projected area of contact was $\frac{1}{2}$ the total cross section of the strut.

In Case 2, the bearing surfaces were plane, so as to concentrate the load near the axis.

In Case 3, the ends were of the same diameter as the strut, but the radius was greater than that of the end surface of the strut in the ratio 16/15. Here, (as in Case 2) the pressure would become more and more spread out with increasing load.

Case 4 was intended to represent approximately the actual conditions expected. The seatings were again of full width, and of the same radius as the strut end surfaces for a diameter one half that of the strut, being then increased to a spherical radius $1\frac{1}{2}$ times that of the end surfaces.

Experimental Results

The results are shown in Fig.3 where the portion over which the stress appears sensibly uniform has been marked in each photograph.

Interpretation of the Figures is obtained by considering the cylinder to be made up of a large number of thin laminae of thickness δt normal to the light path. Where the stress is entirely axial and denoted by \hat{x} , the relative retardations of successive laminae are additive, giving a fringe order proportional to $\int \hat{x} dt$ through the model. Where the stress has a radial component, however, the direction of principal stress changes along the light path, and the relative retardations are no longer additive. For a ray passing through the axis of the cylinder, however, we have a fringe order proportional to $\int_{-r}^r (\hat{\theta} - \hat{x}) dt$, r being the radius of the strut,

and this is constant in the x direction only in the portion where the stress is uniform. The state of uniform stress is thus indicated by

- (a) uniform brightness (or darkness) along the axis
- (b) straightness of the fringes near the axis.

Sensitivity of Observation

In Case 4, Fig.3 the fringe order at the centre is bordering on 9, and a change of $\frac{1}{8}$ order would be easily noticeable in the central region.

Thus it can be estimated that, in the portion marked, $\int_{-r}^r (\theta\theta - \kappa\kappa) dt$ is constant within 1 in 72 i.e. within about $1\frac{1}{2}\%$.

The length of the uniform region corresponds to a length of $2\frac{1}{2}$ inches in the full-size strut (overall length 16 inches). This length is considerably less than indicated by the rule quoted above (see footnote, p.1).

Conclusions

The results show that the strut, as designed, will be in sensibly uniform stress (under axial loading) for a distance of $1\frac{1}{2}$ inches each side of the middle section.

After bedding in, the surface of the seatings will be expected to give contact over the indented area at full load only. This indented area, projected, is expected to be no greater than half the cross section of the strut. The variation in end load distribution, between no load and full load is likely to be from about $\frac{1}{4}$ to $\frac{1}{2}$ the strut sectional area. As this variation is considerably less than that between the extreme cases 2 and 3 in the above photo-elastic tests, the constancy of the strain-load factor will be greater than 1 in 72. During an actual test, the range of loading would usually be much smaller than the capacity of the machine, and the variation in the strain load factor correspondingly less.

It is concluded, therefore, that constancy of the strain load factor will be achieved well within 1 per cent over the middle $2\frac{1}{2}$ inches of the bar.

Appendix

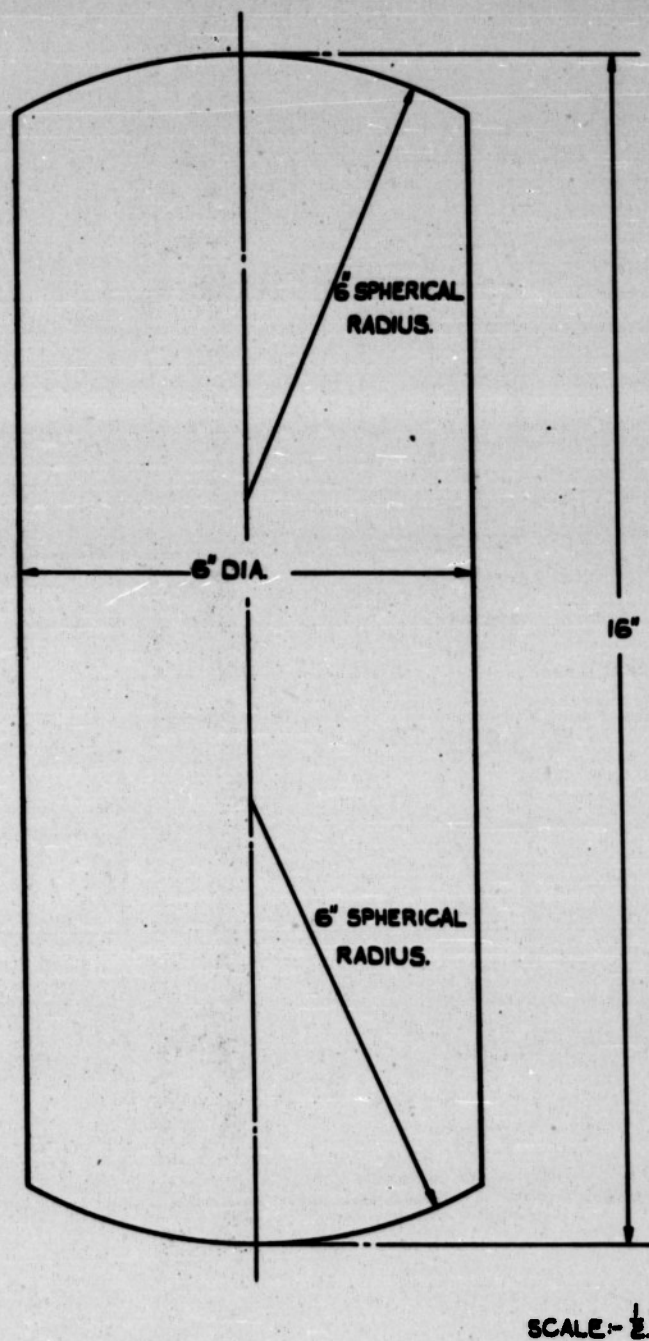
The composition of the immersion liquid to give the same refractive index as Catalin 800 is:-

α -Bromonaphthalene	3 parts
Aniline	11 parts

Attached: Figs.1 and 2 - Drg.Nos. S.M.E.16627/R and S.M.E.16628/R
Fig.3 - Neg.No.71890

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SCALE - $\frac{1}{2}$

FIG. I. DIMENSIONS OF STEEL STRUT.

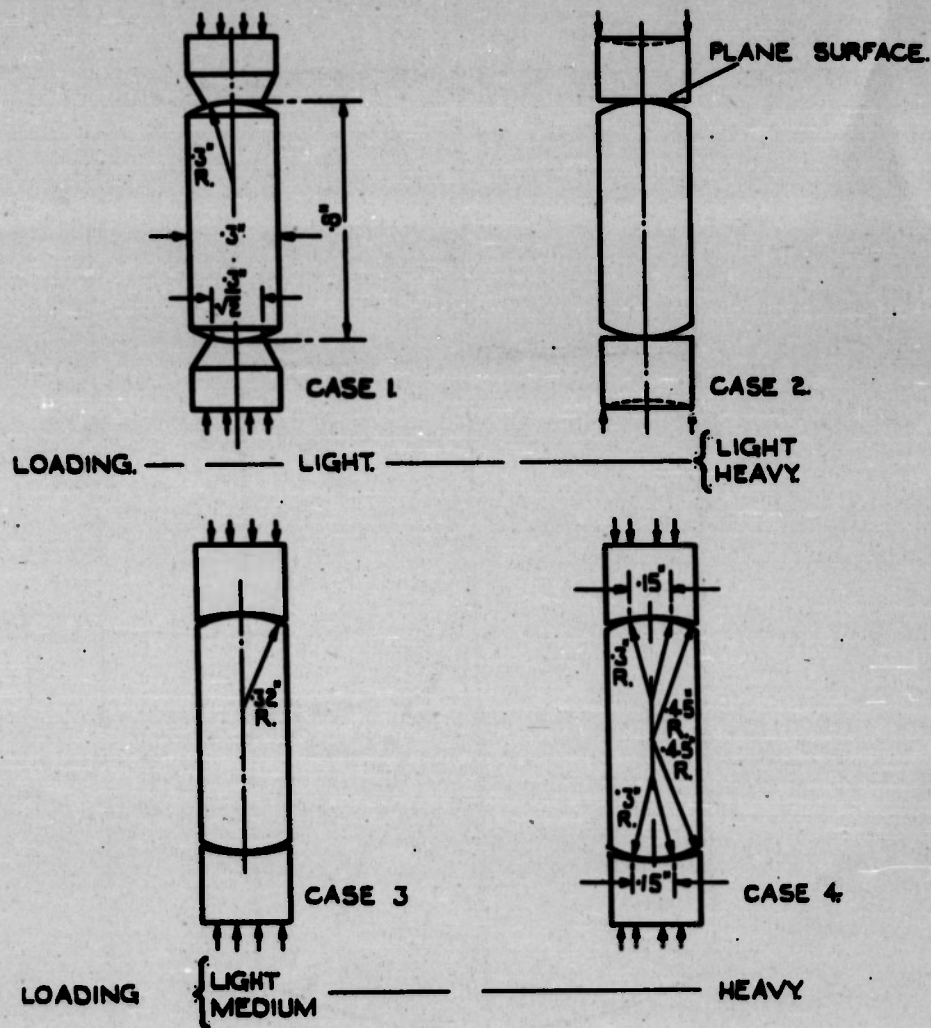
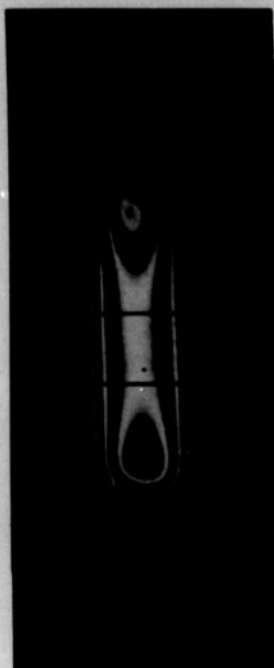
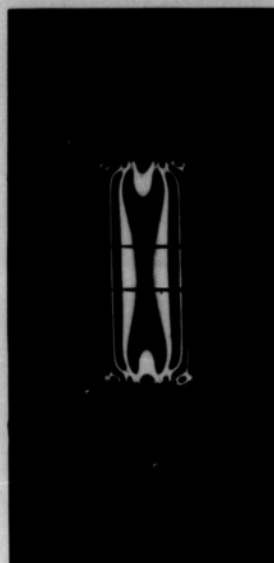


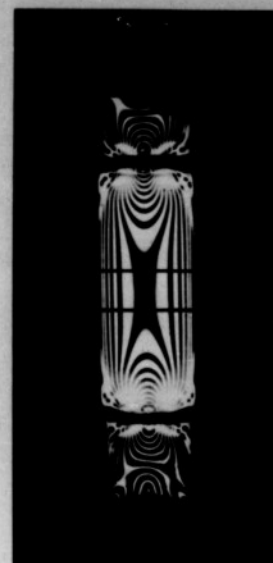
FIG. 2. SHAPES OF SEATING TESTED.



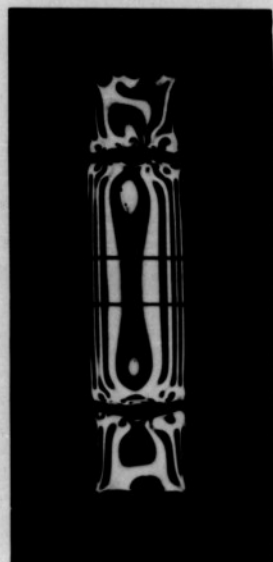
CASE 1
LIGHT LOADING



CASE 2
LIGHT LOADING



CASE 2
HEAVY LOADING



CASE 3
LIGHT LOADING



CASE 3
MEDIUM LOADING



CASE 4
HEAVY LOADING

R.A.E. NEG. NO. 71890 /46.

PHOTO-ELASTIC MODEL OF CYLINDRICAL STRUT
(FOR AVERY 100-TON TESTING MACHINE)

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REV. 23 Jan ' 52

Royal Aircraft Establishment, Farnborough, England
(Report No. SME 3400)

PHOTO-ELASTIC EXAMINATION OF A CYLINDRICAL
STRUT INTENDED FOR RECORDING COMPRESSIVE
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PHOTO-ELASTIC EXAMINATION OF A CYLINDRICAL STRUT
INTENDED FOR RECORDING COMPRESSIVE LOADS - AND APPENDIX

FISHER, W.A.P. JAN¹47 4PP PHOTO, DIAGRS

AERONAUTICAL RESEARCH COUNCIL, MINISTRY OF SUPPLY, ENGLAND
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STRUTS - STRESS ANALYSIS
PHOTOELASTICITY

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STRAIN GAGES

was found that a strut 16 in. long and with a 6-in. diameter has virtually uniform distribution over the middle 2 1/2 in.

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